Simulation and Design of Printed Circuit Boards Utilizing Novel Embedded Capacitance Material

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- *Impedance Simulation Comparison for boards with ECM or FR-4 Power/Ground Core*
- *Comparison of the power noise measurement*
- *In Board Interference Analysis for ECM and FR4 Board*
- *ECM Impact to Signal Integrity*
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Embedded Capacitance Material Introduction

- Planar sandwich structure ECM
- Higher capacitance density than thin core FR4
- Higher decoupling bandwidth than discrete MLCC caps
- 3M C-PLY19
  19um filled insulation
  >6nf/sq inch C/A

Electrical parameters comparison
FR4 plate capacitance vs ECM (3M C-PLY19)

### Materials name

<table>
<thead>
<tr>
<th>Parameters</th>
<th>FR-4 (PCB plate capacitor)</th>
<th>3M C-PLY19 (Embedded capacitor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td>FR4</td>
<td>Epoxy/Ceramic filler</td>
</tr>
<tr>
<td>Dielectric constant (DK)</td>
<td>≥4.0–4.5</td>
<td>21</td>
</tr>
<tr>
<td>Dielectric consumption (DF)@1GHz</td>
<td>≥0.02</td>
<td>0.03</td>
</tr>
<tr>
<td>Dielectric thickness (um)</td>
<td>≥0.68</td>
<td>19</td>
</tr>
<tr>
<td>Capacitance density (nF/inch³)</td>
<td>≤0.3</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Frequency response comparison, MLCC vs ECM

Schematic illustration of 3M C-PLY19

Schematic illustration of PCB plate capacitor
Impedance Simulation Comparison for boards with ECM or FR-4 Power/Ground Core

- Same board stack up and layout
- Only difference in Pwr/Gnd core material
- Impedance port set on same position in simulation
- Much lower impedance of ECM from 10MHz~6GHz than FR4
- Much more resonance in FR4 curve, higher impedance and power noise

Sample board Stack up

<table>
<thead>
<tr>
<th>Layer name</th>
<th>Layout figures</th>
<th>Layout explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>pp(FR4)</td>
<td>TOP (GND)</td>
</tr>
<tr>
<td>L2</td>
<td>core(FR4)</td>
<td>SIGNAL</td>
</tr>
<tr>
<td>L3</td>
<td>core(FR4) or 3M c core</td>
<td>POWER</td>
</tr>
<tr>
<td>L4</td>
<td>core(FR4)</td>
<td>GND</td>
</tr>
<tr>
<td>L5</td>
<td>pp(FR4)</td>
<td>SIGNAL</td>
</tr>
<tr>
<td>L6</td>
<td>pp(FR4)</td>
<td>BOTTOM (GND)</td>
</tr>
</tbody>
</table>

Impedance Comparison
Blue for ECM
Red for thin core FR-4 plate capacitor

FR-4 PCB

3M C-PLY19 PCB
Comparison of the power noise measurement

- Power noise ripple of FR4 board is much higher than that of ECM board.
- ECM board shows superiority over FR4 on noise reduction in entire bandwidth 10MHz-4GHz.
- ECM board noise close to white noise of Spectrum Analyzer in higher frequency over 1.5GHz.
- Very promising for ECM to improve power supply quality, digital /analog interference in board & board level EMI.
In Board Interference Analysis for ECM and FR4 Board

- Port set on same connectors position on FR4 / ECM board
- Transmission coefficient between same ports of ECM board is much lower than that of FR4 board
- ECM board minimized risk for interference from shared power distribution system within board
In Board Interference Analysis for ECM and FR4 Board

- Set noise source and noise probe on same position of FR4 / ECM board
- Same noise source input
- smaller noise distribution area and lower noise amplitude on power plane for ECM board
In Board Interference Analysis for ECM and FR4 Board

- Same noise source and probe setup
- Superior noise spectrum of ECM board in all frequency range


- Same functional circuit on the board for FR4 and ECM board
- 50MHz & 125MHz clock on different zone but with same power
- 125M Clock as aggressor
- 50M clock as victim to see its signal wave and spectrum received
- 50M clock on ECM board less influenced by 125M clock with better jitter and duty cycle

Comparison of the 50 MHz clock signal measured wave

Comparison of the 50 MHz clock signal frequency spectrums on ECM and FR4 board
Board Level EMC Performance Comparison -- Simulation

- With same noise source excitation, free space field and 3 Meter field result of ECM board is lower than that of FR4 in all bandwidth simulated.

EMI simulation result (3 Meter field)

PCB FR4(3.54mil)

PCB 3M C-PLY19 (0.75mil)

Free space field distribution
Full Wave Darkroom

- Radiated Emission Test in standard full wave darkwave for FR4/ECM board.
- Obvious better performance of ECM board from 30M to 2G (only tested up to 2G)
The Application Prospect of the Embedded Capacitance Materials

Due to excellent performance of Embedded Capacitance Material in SI, PI, EMC, it will be well suitable for application in:

1. Digital/analog Interference Design with Digital/analog Mixed Board
2. EMC Design of the Non-shielding Box-type Products with Plastics shell
3. Power Integrity and Signal Integrity Design of the High Speed and High Density Board